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KANAWHA RIVER INVESTIGATION

REPORT ON BENEFITS TO POLLUTION ABATEMENT FROM INCREASED MINIMUM FLOWS ON THE KANAWHA THROUGH REGULATED RELEASES FROM SUMMERSVILLE AND SUTTON RESERVOIRS

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16. Abstracts Sutton Reservoir and Summersville Reservoir were intended to provide through storage sufficient water to augment the low flows of the Kanawha River in West Virginia with considerable benefit to pollution abatement, water supply, river water temperature reduction (beneficial in summer months), and to some extent, to sewage treatment in the Cincinnati-Covington Pool on the Ohio River. Maintenance of a given rate of flow is used in design rather than adding the amount of augmentation to the natural flows. A high degree of waste treatment or a large reduction in waste load added to the Kanawha is necessary even with the highest rates of low flow augmentation. Secondary treatment of muncipal wastes and equivalent reduction of organic industrial waste loads were found to be necessary if the minimum water quality objectives of the West Virginia State Water Commission were to be met.

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INTRODUCTION

This report has been prepared at the request of the District Engineer, Corps of Engineers, U. S. Army, Huntington District, Huntington, West Virginia. Essentially it is a re-evaluation of a series of previous reports on the Kanawha River prepared by the Public Health Service, plus new studies based on data collected since previous reports were prepared.

New evaluations were made for augmentation flows of 50, 100, 200, and 300 cfs from the Sutton Reservoir on the Elk River, and 200, 500, and 1,000 cfs from Summersville Reservoir on the Gauley River.

SUMMARY

Sutton Reservoir now under construction and the proposed Summersville Reservoir could provide through storage sufficient water to augment the low flows which occur on the Kanawha with considerable benefit to pollution abatement, to water supply, to river water temperature reduction which would be beneficial during the summer months, and to some extent to sewage treatment in the Cincinnati-Covington Pool on the Ohio River. Maintenance of a given rate of flow is used in design rather than adding the amount of augmentation to the natural flows. Values of varying rates of augmentation are tabulated for both Summersville and Sutton Reservoirs.

A high degree of waste treatment or a large reduction in waste load added to the Kanawha River is necessary even with the highest rates of low flow augmentation. For all conditions examined, secondary treatment of municipal wastes and equivalent reduction of organic industrial wastes loads were found to be necessary if the minimum water quality objectives of the West Virginia State Water Commission are to be met.

CONCLUSIONS

1. Pollution abatement benefits are approximately equal on the main stem of the Kanawha River for equal flows whether they came from Sutton Reservoir or Summersville Reservoir. Each increment of low flow augmentation has approximately equal monetary value for the range of flows covered in this study. However, small increases in flow may not have an actual monetary value due to construction and operating conditions for each industrial waste. For an augmentation of 50 cfs, the waste load should be reduced 78.5% and would provide an annual benefit of $40,700. For an augmentation of 1,000 cfs the waste load should be reduced 71.8% and would provide an annual benefit of $815,000. For increases in flow between these rates the annual value would be proportional. These values are based on a low flow of 2,140 cfs during the summer months having a frequency of once in ten years. Pollution abatement benefits on the Elk River occur only for flow increases from Sutton Reservoir, require 50 cfs, and reduce treatment requirements from complete treatment to primary treatment only.

2. The data on which these evaluations are based are in substantial agreement with the organic load values supplied by industry with the exception of the Nitro area.

3. Industry in general places no immediate value upon temperature reduction.

4. Water supply benefits accrue only to low flow supplements from Sutton Reservoir on the Elk River. These benefits are computed from the cost required to supply 50 cfs to the Elk River by means of a small impounding reservoir on a tributary of the Elk River. No increase in benefits to water supply are shown for flows in excess of 50 cfs. Although indeterminate benefits for the present and some benefits for increased water supply demands many years in the future may be realized. The cost of this impoundment is divided between pollution abatement on the Kanawha River of $40,700 and water supply directly from the Elk River of $99,300 converted to a yearly basis.

5. Minor benefits such as hardness and chloride reduction to industry or others are not included as their value is too indeterminate.

6. The benefits to the Cincinnati-Covington area on the Ohio River were taken from the 1951 report and increased 20% to allow for rising chemical costs.

7. The annual monetary benefits discussed above are summarized in Table I.

Previous Reports

The latest previous report was that of July 3, 1951, entitled "Memorandum Report-Summersville Reservoir, supplement to report 'Kanawha River Investigation-Benefits to Pollution Abatement from Increased Low-water Flow'" and was prepared by the Public Health Service for the District Engineer, Huntington District, Corps of Engineers, U. S. Army.

The report "Kanawha River Investigation, Benefits to Pollution Abatement from Increased Low-water Flow" was prepared in June 1945 for the Division Engineer, Ohio River Division, Corps of Engineers, U. S. Army.

The Kanawha River Basin was included as a part of the Ohio River Pollution Survey conducted during the period from 1939 to 1941. The results of this survey were published as House Document 266, 78th Congress, 1st Session, "Ohio River Pollution Control."

Scope of this Report

This report supplements previous reports on benefits considered to be attributable to low flow augmentation so as to maintain certain minimum flows on the main stem of the Kanawha River. Flow regulation from both Sutton Reservoir and Summersville Reservoir is considered.

The evaluation of low flow benefits includes benefits to the oxygen requirements of the stream and to public water supplies. These benefits are evaluated separately and then are summarized. This report deals primarily with conditions on the main stem of the river from Glasgow to Winfield, and on the Elk River.

Physical and Chemical Data Available

a. Hydrologic Data: Stream flows were obtained from the U. S. Geological Survey. These data were supplemented by interpolation and by averaging where necessary to conform with other data used in the analysis. Data on discharge through turbines at Winfield, Marmet and London were furnished by the Appalachian Electric Power Company. Flow duration curves were developed by the U. S. G. S. and the Corps of Engineers, Ohio River Division. The flow used in design and development of benefits was taken from the low flow frequency curve for the four summer months of June, July, August, and September of the Kanawha River at Kanawha Falls for the period 1899-1935, developed by the Ohio River Division in September 1941. The frequency of low flow was that which was equalled or exceeded once in ten years.

b. Stream Sampling Data: Stream sampling data from 1946 to 1955 inclusive were furnished by the West Virginia State Water Commission. The best available data, and that used for the development of this report, were obtained during the period

Table I.

Summary of Benefits from Low Flow Augmentation

(A) Summersville			
Low Flow Augmentation cfs	200	500	1,000
Source of Benefit			
Pollution Abatement[1] Kanawha River	$163,000	$407,500	$815,000
Cincinnati-Covington Area[4] Est. Aug. Annual Savings in Chemical Costs	-	3,000	6,000
Totals	$163,000	$410,500	$821,000

Table I (Continued)

Summary of Benefits from Low Flow Augmentation

(B) Sutton Low Flow Augmentation cfs	50	100	200	300
Source of Benefit				
Pollution Abatement[1] Kanawha River	$ 40,700	$ 81,500	$163,000	$244,500
Pollution Abatement[2] Elk River	7,200	7,200	7,200	7,200
Water Supply[3]	99,300	99,300	99,300	99,300
Totals	$147,200	$188,000	$269,500	$351,000

Notes:

(1) Alternate method construction costs amortized in 20 years at 4% (industrial wastes).

(2) Alternate method construction costs amortized in 20 years at 2¾% (municipal treatment).

(3) Alternate method construction costs amortized in 50 years at 4% (private development).

(4) Taken from 1951 Report p. 6 increased 20%.

26 September - 4 October 1949. At that time, the Kanawha River was sampled at ten different mileage indices, with three points on each mileage index, at one-half the depth of the water. Ten field crews from the State Water Commission and from Industry were used to collect the samples simultaneously. Eight samples were taken at each point on the half-hour, beginning at 8:30 AM and ending at 3:30 PM. The B.O.D. samples were composited for testing whereas the D.O. samples were tested immediately and the results averaged. Other determinations were also made from these samples. During all other periods, only grab samples were obtained for analysis. Total data available includes coliform organisms, water temperature, pH, dissolved oxygen, 5-day 20°C B.O.D., alkalinity, hardness, chlorides, and odor.

Supplementary data on odors in the raw water from the Kanawha River at Nitro were obtained from "Drinking Water Taste and Odor" by Middleton, Grant, and Rosen published in Industrial and Engineering Chemistry, Vol. 48, p. 268, February 1956.

Temperature data for the period March 1953 - September 1955 were obtained for Kanawha River at Charleston by the U. S. G. S.

c. De-oxygenation Rate Data: Studies in recent years indicate that the exponental rate of carbonaceous oxidation (k.) at 20°C rarely has a uniform rate of 0.1 but varies from less than one-half to more than twice this value. This fact throws doubt on the calculation of the ultimate carbonaceous demand (L) of a sample from 5-day B.O.D. values unless the "k" value has been determined on the sewage, waste, or stream under consideration. Additional field and laboratory work was necessary in order to determine the necessary "k" values.

Samples from the Kanawha River were obtained by Public Health Service personnel in cooperation with the Operating Staff of the Marmet Lock and Dam. The "k" determinations were made at the Robert A. Taft Sanitary Engineering Center by Public Health Service personnel. The "k" values thus determined were used to evaluate more accurately the best available stream data.

d. Data on Sources of Pollution: Information on sources of pollution was obtained from the West Virginia State Health Department and the West Virginia State Water Commission. The State Water Commission supplied data on industrial waste loads which were furnished to the Commission by the industries concerned.

e. Miscellaneous Data: Maps and data on the various dams, locks and on the stream channel, also power production and lockages, were furnished by the Corps of Engineers.

f. Cost Data: Costs were determined after consideration of cost information in: (1) Special Report No. 18-s, January 1955, published by the American Public Works Association; (2) Water Supply and Waste Water Disposal by Fair and Geyer; (3) a communication from a Regional office of the Public Health Service; (4) information supplied by a State office; and (5) miscellaneous cost information from the files at the Robert A. Taft Sanitary Engineering Center; (6) the cost of reducing industrial wastes loads was assumed to be the same as equivalent reduction of municipal wastes loads accomplished by conventional treatment methods.

Design Basis:

For pollution abatement and temperature reduction purposes the benefits shown in this report are based on a low flow of 2,140 cfs in the Kanawha River at Charleston, West Virginia, which has a summertime frequency of occurrence of once in ten (10) years. The augmentation rate of flow is then added to this base flow to obtain the rate of flow which is to be maintained in the river for the benefits corresponding to the given augmentations, and the given reduction in waste load discharged to the river. Satisfaction of these design conditions is necessary in order that the dissolved oxygen in the river may be maintained at the minimum objective value of 3 ppm, as proposed by the West Virginia State Water Commission.

The method of applying the low flow increases is indicated in Figure 1. In this case the water temperature for the months of July, August, and September is assumed to be 30°C, while the temperature for October is assumed to be 20°C. The flows shown are those required to maintain a minimum dissolved oxygen content in the river of 3 ppm for the stated reductions in waste loads at the given temperatures. A decrease in temperature below those shown should permit a lower rate of flow than those stated as long as the waste load placed on the river is not greater than the given percentages of the 1949 waste loads.

Most effective utilization of water stored for low flow augmentation could be made if measurements of the dissolved oxygen content of the river water at critical points in the river were made frequently, that is, at points where the dissolved oxygen is the lowest. Evidence at hand indicates that for low flow augmentation from both Sutton Reservoir and Summersville Reservoir there may be at least two critical points, one close to River Mile 46 to 48, and the other close to River Mile 36 to 38. In case frequent dissolved oxygen measurements are impractical the regulation of river flow for pollution abatement purposes could be based upon temperature measurements as presently made by the U. S. G. S. near Charleston, West Virginia, if supplemented by occasional dissolved oxygen measurements at the critical points.

Benefits from Increased Low Flows

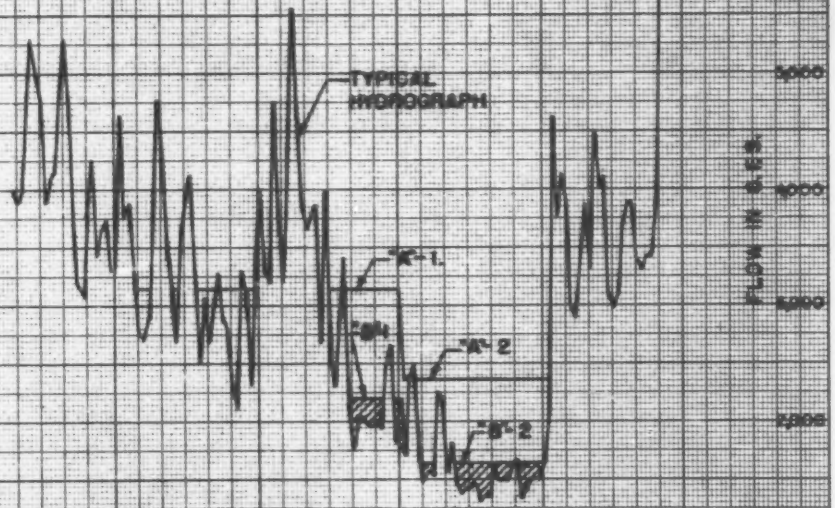
The benefits which will accrue from maintaining the flow in the Kanawha River at or above certain given rates are discussed below under: (a) Pollution Abatement (Organic Loadings) for which ultimate biochemical

JANUARY 5 10 15 20 25 | FEBRUARY 5 10 15 20 25 | MARCH 5 10 15 20 25 | APRIL 5 10 15 20 25 | MAY 5 10 15 20 25 | JUNE 5 10 15 20 25 | JULY 5 10 15 20 25 | AUGUST 5 10 15 20 25 | SEPTEMBER 5 10 15 20 25 | OCTOBER 5 10 15 20 25 | NOVEMBER 5 10 15 20 25 | DECEMBER 5 10 15 20 25

BASE: LOW FLOW AT KANAWHA FALLS, W.VA. IS 2,140 C.F.S. WITH A FREQUENCY OF ONCE IN 10 YEARS FOR THE SUMMER MONTHS.

"A" LOW FLOW AUGMENTATION = 1,000 C.F.S.
1. FLOW MAINTAINED AT 3,140 C.F.S. OR ABOVE WITH WATER TEMPERATURE AT 30°C. (ASSUMED FOR JULY, AUGUST & SEPTEMBER.)
2. FLOW MAINTAINED AT 2,370 C.F.S. OR ABOVE WITH WATER TEMPERATURE AT 20°C. (ASSUMED FOR OCTOBER.)
WASTE LOAD NOT GREATER THAN 28.2% OF 1949 LOAD.

"B" LOW FLOW AUGMENTATION = 30 C.F.S.
1. FLOW MAINTAINED AT 2,190 C.F.S. OR ABOVE WITH WATER TEMPERATURE AT 30°C. (ASSUMED FOR AUGUST & SEPTEMBER.)
2. FLOW MAINTAINED AT 1,680 C.F.S. OR ABOVE WITH WATER TEMPERATURE AT 20°C. (ASSUMED FOR OCTOBER.)
WASTE LOAD NOT GREATER THAN 21.5% OF 1949 LOAD.



KANAWHA RIVER STUDY
ILLUSTRATION OF LOW FLOW AUGMENTATION
MINIMUM D.O. = 5 p.p.m.
1 SEPTEMBER 1956

FIGURE 1

5 10 15 20 25 JANUARY | 5 10 15 20 25 FEBRUARY | 5 10 15 20 25 MARCH | 5 10 15 20 25 APRIL | 5 10 15 20 25 MAY | 5 10 15 20 25 JUNE | 5 10 15 20 25 JULY | 5 10 15 20 25 AUGUST | 5 10 15 20 25 SEPTEMBER | 5 10 15 20 25 OCTOBER | 5 10 15 20 25 NOVEMBER | 5 10 15 20 25 DECEMBER

oxygen demand of the waste loads and dissolved oxygen content of the river water are of primary importance; (b) Water Supplies and Odor; (c) Other considerations including toxic conditions; and (d) Temperature Reduction.

a. Organic Loadings: The ability of a stream to assimilate organic material and still maintain satisfactory conditions from the standpoint of recreation (including boating, fishing and swimming) and from the standpoint of nuisance prevention depends upon the rate at which the organic material uses up oxygen, upon the initial amount of oxygen present in the stream, and upon the rate at which oxygen is absorbed or dissolved by the stream. Data from sources previously mentioned were utilized in determining the oxygen sag and the reaeration coefficients along the Kanawha River. This information was then used in determining the reduction in biochemical oxygen demand required for various flows from 1,500 cfs to 4,500 cfs on the Kanawha River. The effect of increasing the flow on the Kanawha River at the mouth of the Elk River was compared to increases added at the mouth of the Gauley River. No significant differences in required B.O.D. reductions were obtained for given rates of flow below Charleston between low flow augmentation from Sutton Reservoir in the 50 to 750 cfs range and the same amounts of low flow augmentation from Summersville Reservoir. The primary difference between augmentation from Sutton Reservoir and Summersville Reservoir is that the low dissolved oxygen content persists over a longer stretch of the river and for a longer time for flow augmentation from Sutton Reservoir than for the same flow augmentation from Summersville Reservoir, with the base flow the same in each case. Hence, no further distinction is made as to the source of low flow augmentation for B.O.D. reductions.

The loadings indicated by analysis of the data and as determined from the reports supplied by industry are as shown in Tables II(a) and II(b). The loads were grouped for convenience and because the data did not permit accurate division into individual loads.

Data on waste loads discharged into the Kanawha River have been furnished by the industries producing the wastes. A few small industries have not reported, but most of those discharging large amounts of wastes have reported. The total ultimate B.O.D.s as computed from this information plus the municipal loads shows very good correlation between the maximum loads reported by industry and the loads found by means of the B.O.D. profile with the exception of the load at Nitro which is 82% less than the load computed from the profile loads obtained from the 1949 data supplied by the State Water Commission. There is great variation in the loads from month to month at certain plants as shown by the tabulations supplied. It is presumed that there is even greater variation from day to day in these waste loads as the grab-sample data from the State Water Commission indicates a large variation in these loads. Since no known industrial wastes treatment plants exist at any of these plants other than lagooning at one plant, it is presumed that the reduced waste loads indicate better housekeeping practices at each plant where a lower load than the 1949 load has been reported by an industry.

If the waste loads discharged to the Kanawha River could be maintained at a value not greater than 28.2% of the 1949 loads or 1,083,000 P.E., then a low flow augmentation of 1,000 cfs should be sufficient to maintain a minimum D.O. of 3 ppm under the previously stated design conditions. This is only a P.E. of 69,000 less than the lowest value of the total P.E. as calculated from the reports from industry. Thus: with a consistent effort on the part of industry; with a maintenance of a low flow of 3,140 cfs when the temperature of the water is 30°C and of 2,370 cfs when the temperature is 20°C; with no short time fluctuations below these values; and with a further reduction below reported loads of only 60,000 to 100,000 P.E.s the condition of the Kanawha could be brought up to the minimum dissolved oxygen objective of the West Virginia State Water Commission. It should be kept in mind that this is based on a frequency of one year in ten years for the low flows used.

The low flow which has a frequency of once in ten years is considered to be realistic. Two values are utilized, one based on the low flows for the months of June, July, August and September (called summer flow) with a flow of 2,140 cfs, for which a water temperature of 30°C was used, and the other an October flow of 1,500 cfs for which a water temperature of 20°C was used.

Records furnished by the Appalachian Electric Power Company show large variations in discharge through their turbines within a 24-hour period at each of the three main river dams - Winfield, Marmet and London. Most of this fluctuation is no doubt due to variation in power load requirements. As shown in the 1951 report some daily hydrographs show extreme variation in the flow in the river from hour to hour. This fluctuation increases the maximum oxygen depletion of the river. In order that the benefits for any given flow may be fully realized the flow should not be less than the given amount even for short periods of time. Fluctuations in flow for power purposes would not decrease the benefits of low flow augmentation as long as the minimum is kept above the flow for which the benefits are computed. However, industry might be better able to regulate their waste load discharged to the stream so as to maintain a minimum D.O. of 3 ppm if the stream flow did not fluctuate excessively.

The waste treatment or equivalent reductions required (in per cent of the 1949 waste load) in order to maintain a minimum dissolved oxygen of 3 ppm in the river for various flow increases from Sutton and/or Summersville Reservoirs and the total annual values of low flow augmentation or increases are shown in Table III.

The values shown in Table III are based on the analysis of the data which indicate that each cubic foot per second of flow increase has equal value within the range of flows studied. Small increases such as 50 cfs from one source may have very little value for decreasing the waste treatment required unless accompanied by other larger increases from other sources. The total ultimate increase should not be less than 300 to 500 cfs to be effective in reducing treatment costs.

Table II(a)

Population Equivalents

Location	Load - (From 1949 Data)	
	Ultimate B.O.D. in 1,000 lbs./day	Population Equivalents in 1,000's
Belle Industries plus municipal	208	832
Charleston Municipal and Elk River	72	288
Charleston Industries	300	1,200
Institute Industries plus municipal	126	504
Nitro Industries plus municipal	254	1,016
Totals	960	3,840

Table II(b)

Population Equivalents

Sta. Mile	Industry or City	Population Equivalents of Wastes Calculated: Min. by Rpt. frm. Ind.	Frm. Est. Pop. of City	Min. Ind. Plus City	Max. by Rept. frm. Ind.	Max. Ind. Plus City	Val. frm. 1949 River Profile	(8)-(7)x100 / (8) = %
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
68.3	Belle Industries	133,000	-	-	619,500	-	-	-
68.3	To Belle frm. Cities	-	14,000	-	-	-	-	-
68.3	Sub-Totals	-	-	147,000	-	634,000	832,000	+24
57.8	Charleston Plus Est. Elk River	-		69,000	-	151,000	288,000	+49
54.5	Charleston Industries	254,300	-	254,000	1,178,000	1,178,000	1,200,000	+ 2
48.9	Institute Industries	552,000	-	-	552,000	-	-	-
52&49	Dunbar & Institute Industries	-	7,000	-	-	-	-	-
48.9	Sub-Totals	-	-	559,000	-	559,000	504,000	-11
43.0	Nitro Industries	175,500	-	-	175,500	-	-	-
46&43	St. Albans & Nitro	-	7,900	-	-	-	-	-
43.0	Sub-Totals	-	-	183,000	-	183,000	1,016,000	+82
	Totals			1,212,000		2,704,400	3,840,000	+30

Table III

Pollution Abatement Benefits From Low Flow Augmentation

Low Flow Augmentation cfs	Summer Flow(30°C) Maintnd.at or Above cfs	Equiv.Oct.Flow (20°C)Maintnd. at or Above cfs	% Waste Trtmt.Req. for Min.D.O.=3 ppm (Based on 1949 Data)	% of 1949 Waste Loads Discharged to River	Total Annual Value of Aug. Flow $
50	2,190	1,630	78.5	21.5	40,700
100	2,240	1,680	78.1	21.9	81,500
200	2,340	1,750	77.4	22.6	163,000
300	2,440	1,830	76.7	23.3	244,500
500	2,640	1,980	75.3	24.7	407,500
1000	3,140	2,370	71.8	28.2	815,000

Note: The source (Sutton or Summersville Reservoirs) of the low flow augmentation is of little significance as far as pollution abatement benefits are concerned.

The data obtained by the West Virginia State Water Commission indicate that no significant change has occurred in the minimum dissolved oxygen remaining in the river water during the period 1946 to 1955 for the stretch of river from Belle to Winfield. This minimum reaches zero on many occasions. The total B.O.D. loading indicated for 1955 is of the same order of magnitude as the total for 1949. Since the samplings made in the 1949 period were more extensive than for any other period, the analytical results determined from the 1949 samplings were used in analyzing the problem.

The benefits estimated herein are contingent upon the maintenance of continuous flows at or above the values shown. Short time fluctuations due to power requirements could easily cancel most of the benefits. When the augmentation flows are superimposed on the base flow the minimum of 3 ppm of dissolved oxygen can only be expected if the current waste load is not in excess of those corresponding to the percentages of 1949 loads shown in Table III.

Benefits to pollution abatement on the Elk River due to low flow increase will affect Gassaway, Sutton and Clendenin. The minimum flow increase of 50 cfs proposed from Sutton Reservoir will permit satisfactory disposal of municipal wastes from these three communities with primary treatment. The populations used for computing these benefits were taken from the 1956 report of the West Virginia Department of Health on "Public Water Supplies in West Virginia."

Municipality	Estimated Sewered Population
Gassaway	1,600
Sutton	1,300
Clendenin	2,000
Total	4,900

The difference between the costs of constructing a primary treatment plant and a complete treatment plant is taken as $15.00 per person, or $73,500.

Amortization (20 years @ 2½%)	$4,700
Annual saving in operation costs at 50¢ per person	2,500
Total annual benefits of pollution abatement on the Elk River	$7,200.

Benefits to pollution abatement on the Gauley River due to low flow increase will affect a few small communities but would be too small and indeterminate to include in this report.

b. Water Supplies and Odor: Odors and the tastes associated with them are particularly important at locations where municipal water supplies are obtained from the Kanawha River. The Elk River is the source of water supply for Charleston and some adjoining areas. Nitro obtains its water supply from the Kanawha River, thus this supply is directly affected by odor in the Kanawha River water. Other supplies serving smaller communities also are obtained from the Kanawha River.

According to the records as furnished by the West Virginia State Water Commission odor conditions have improved at all stations sampled through the period 1946 to 1955 and extending from above Belle to below Winfield. Above the Charleston Industries the maximum odor number was 2,000 before 1949 whereas for 1949 and later years through 1955 the maximum odor number was 100. The corresponding mean odor numbers were 33 and 5 respectively. Below Charleston the maximum odor number was 10,000 before 1949 whereas for 1949 and later years through 1955 the maximum odor number was 666. The corresponding mean odor numbers were 263 and 157. For all of these odor numbers some treatment of the water for odor removal would be required to make the water satisfactory for domestic use. For water users below Charleston extremely extensive special treatment would be required to produce a palatable water. A paper by Middleton, Grant and Rosen on "Drinking Water Taste and Odor" published in Industrial and Engineering Chemistry for February 1956 reports an average threshold odor number as 12,500 for the period December 22 to 28, 1951. This is far in excess of any reported by the State Water Commission. Under such conditions it becomes impractical to provide a satisfactory drinking water.

Water supplies above Charleston on the Kanawha and Gauley Rivers will benefit to some extent from increased low flows provided by Summersville Reservoir, as the added water will provide some dilution for the odor producing substances to be found in the water. Public water supplies using the Kanawha and Gauley Rivers as a source located above Charleston provide an average of over 2 MGD. Some benefit to water supplies on the Elk above Charleston will be provided by flow supplement from Sutton Reservoir as about 0.5 MGD is used by public water supplies omitting Charleston with the Elk River as a source. However, by far the largest benefit will accrue to the Charleston and Nitro water supplies. (These two plants supply water to the towns and industries located between them except for St. Albans which utilizes the Coal River for its source of supply). The Nitro plant provides an average of 4 MGD from the Kanawha River while the Charleston plant provides an average of 14 MGD from the Elk River supplemented by Kanawha River water during periods of unusually low flow on the Elk River. Since the Elk River water will be of better quality it is assumed that water will be furnished from the Charleston water plant to the Nitro system. The present average demand at these two plants is about 18 MGD or 27.8 cfs. To provide adequately for variations

in demand and for an increase in demand in the near future a low flow of 50 cfs for water supply purposes is used.

The greatest benefits to water supply will thus be in the Charleston-Nitro area. Other minor benefits are ignored. After a consideration of alternate methods of eliminating taste and odors in these water supplies and of providing sufficient water for the Charleston plant it was found that the most appropriate would be to provide the needed water by storage on the Elk River. As a means of estimating the value of these benefits the cost of providing the needed water by means of a single purpose reservoir on the Elk River or on a tributary of the Elk was calculated on the basis of a minimum flow of 50 cfs. The flow would require a storage of about 17,800 acre feet. The annual cost of this reservoir at 4% interest and a life of 50 years would be approximately $140,000. Assuming that this impoundment was provided on a tributary below Clendenin this cost would include benefits to pollution abatement on the main stem of the Kanawha but would not include benefits to pollution abatement on the Elk River itself. Since Table II shows $40,700 as the annual benefit for pollution abatement on the Kanawha River for 50 cfs, the net annual cost chargeable to water supply is thus $99,300.

c. Other Pollutional Considerations: Segregation of industrial wastes at their sources presents an opportunity to improve stream conditions in the Kanawha River for recreational, water supply and even industrial uses. Any wastes toxic to aquatic life particularly to fish should be separated from the other wastes and kept at as small a volume as practicable. Disposal elsewhere rather than in the river where feasible is highly desirable. Housekeeping practices which reduce the amount of the waste would reduce the concentration of such wastes in the river. Any treatment provided for the industrial waste would reduce the concentration of toxic wastes in the river. Low flow augmentation also would decrease this toxic waste concentration. The value attached to this factor of pollution abatement may be rather large. However, no information is at hand by which an evaluation in terms of money may be made.

d. Temperature Reduction: The study of effects of a reduced water temperature on production costs of the Kanawha River Industries is complex. To develop this value for any one industry would apparently require a special study by that industry's personnel as no data on benefits of a lower river temperature have been reported. The eleven industries reporting on this subject implied that the value was indeterminate and probably of very little benefit.

The reservoirs, Sutton and Summersville, are so distant from the industries that it must be assumed that in the summer, the cooler waters withdrawn from the depths of the reservoir approach a state of temperature equilibrium between the river and air before reaching the industries. Any effect of temperature reduction would only be accomplished by dilution of the base flow by the augmented flow.

The Kanawha River will pick up a heat load of approximately 4.65×10^9 BTU/Hr. from the proposed 1,000,000 KW power plant at Glasgow. However, that plant will have cooling water unaffected by dilution as there is little heat discharged to the river above Glasgow. Any benefit to this proposed plant should be based upon sustained flow rather than temperature reduction, and should be the subject of a separate study made with full knowledge of design concepts used by the power company. Such a study is believed to be beyond the scope of this report.

There has been much concern over the effect of the proposed power plant heat load wasted to the river on temperatures of the river water downstream. A calculation has been made using the heat load of 4.65×10^9 BTU/Hr. with a base flow of 2,140 cfs and then augmenting that base flow with 1,000 cfs and 500 cfs. The temperature reductions were determined for several mileage stations and are tabulated below:

Station Mile	Reduction of Temperature °F due to augmentation flows	
	1,000 cfs	500 cfs
75.5	2.8	1.6
72.5	2.3	1.3
69.5	2.1	1.2
54.5	1.0	0.5
48.5	0.7	0.4
42.5	0.5	-

It can be noted from the tabulation that as the river flows further downstream, it again approaches equilibrium with the air temperature. For this reason the benefits computed apply only to Summersville.

One 295,000 KW power plant is located below the proposed Glasgow power plant. Temperature decreases from temperatures caused by Glasgow Power Plant have been calculated to be about 2.5°F for an augmented flow of 1,000 cfs and 1.5°F for an augmented flow of 500 cfs. From data obtained on a power plant located on the Ohio River, it was observed that the efficiency of that plant was 2½ per cent greater when the cooling water was at 40°F than when at 80°F. Within these temperature limits, increased efficiency is proportional to the decrease of temperature. Then for each degree of lower temperature, the efficiency would increase by .0625%.

To determine benefits due to a reduced temperature, the following assumptions are made:

a. The temperature will be reduced by augmented flows for a period of 120 days per year.

b. With a plant efficiency of 30%, it requires 11,300 BTU per KWH.

c. Use 14,000 BTU per pound of coal. Coal is valued at $4.75/ton.

Benefits to an Augmented Flow of 1,000 cfs.

River temperature reduction = 2.5°F.

2.5 x .000625 = .15625 per cent improvement for 120 days or on a yearly average, .052 per cent. Then the efficiency would increase from 30.000% to 30.052%.

The savings in BTUs then is calculated as follows:

$$\frac{52}{30,000} \times 11,300 \text{ BTU} = 19.6 \text{ BTU/Hr.}$$

i.e. 19.6 BTU/Hr. for each KW installed and worked for a one-year period.

19.6 x 8,760 Hours per year x 295,000 KW = 50.7×10^9 BTUs per year saved.

$$\frac{50.7 \times 10^9}{14,000} = 3,625,000 \text{ pounds of coal per year}$$

$$\frac{3,625,000}{2,000} \times \$4.75 = \underline{\$8,620.00} \text{ annually.}$$

Benefits to an Augmented Flow of 500 cfs.

Temperature reduction = 1.5°F.

1.5 x .000625 = .0937 per cent improvement for 120 days, or on a yearly average, .0312 per cent. Then the efficiency would increase from 30.000% to 30.0312%.

$$\frac{31.2}{30,000} \times 11,300 \text{ BTU} = 11.7 \text{ BTU/Hr.}$$

11.7 x 8,760 Hours per year x 295,000 KW = 30.4×10^9 BTUs saved.

$$\frac{30.4 \times 10^9}{14{,}000} = 2{,}170{,}000 \text{ pounds of coal per year saved.}$$

$$\frac{2{,}170{,}000}{2{,}000} \times \$4.75 = \underline{\$5{,}150.00} \text{ annually}$$

One of the weaknesses of the above calculation is that the percentages are so small that operating procedure could easily defeat any such savings as shown. However, when equally effective operating procedures are used in the plant, the preceding computed values are believed to be reasonable.

When the proposed 1,000,000 KW power plant becomes operative, then a re-evaluation of the benefit of reduced temperatures in the Kanawha River should be made. At that time, it is believed that each industry will be able to determine benefits to itself caused by reduced river water temperatures.

Correlation - 1951 and 1956 Reports:

While this report is based in part upon the 1949 data as supplied by the West Virginia State Water Commission no determinations of the rates of deoxygenation were available at that time to the Public Health Service. Since the 1951 report was made rates of deoxygenation have been determined permitting more accurate analysis of the 1949 data. This accounts for the increase shown for the organic loadings placed upon the Kanawha River by this (1956) report over the organic loadings shown by the 1951 report. The monetary values are further influenced by changes in cost of operation and construction during the same interval of time.